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This paper briefly summarizes the state of knowledge about (1) the effectiveness of computer-based instruction (CBI), (2) where and how it is being used, (3) some cautions about overgeneralizing from these successes, and (4) what should be done to incorporate it appropriately into Navy training. CBI can be effective, but to use it properly, clear procedures are required to analyze needs, derive requirements, and match them with capabilities of computers. To assist in this process, computer-based aids for authoring instruction are needed along with a support system to provide standardization and distribution. There is much to be learned about how to design effective CBI and to determine where and when it should be used for military training. A programmatic research effort is needed to improve the technology.

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COMPUTER-BASED SYSTEMS FOR NAVY CLASSROOM TRAINING

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AND
DEVELOPMENT CENTER
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COMPUTER-BASED SYSTEMS FOR NAVY CLASSROOM TRAINING

William E. Montague

Reviewed by
E. G. Aiken

Approved by
James S. McMichael

Released by
J. W. Renard
Captain, U.S. Navy
Commanding Officer

Navy Personnel Research and Development Center
San Diego, California 92152-6800

FOREWORD

This report was written at the request of the Commanding Officer and Technical Director of Navy Personnel Research and Development Center to review the current state of computer-based instruction. It briefly summarizes the effectiveness of current computer-based instruction programs, where these programs are being used and by whom, and recommends how to incorporate the technology into Navy training. The results are intended for a general audience concerned with the use of computer-based training systems in military training.

J. W. RENARD
Captain, U.S. Navy
Commanding Officer

J. W. TWEEDDALE
Technical Director

SUMMARY

Purpose and Background

This report briefly summarizes the current state of computer-based instruction (CBI) programs, discusses where these programs are being used and by whom, and recommends how to incorporate the technology into Navy training.

Often thought of as a quick technical solution to Navy training problems, the computer can be programmed to be a substitute teacher and to represent a task. However, the difficulties in describing and designing teaching interactions and programming computers to control the problems are enormous. For 20 years, computer-based systems have been tested that resemble automated and animated textbooks with on-line assessment of learning; these systems can be implemented now.

Recent Research on Computer-Based Instruction (CBI)

In more than 100 comparisons of CBI with traditional (lecture) instruction, researchers found that the achievement of students using CBI were as good and often better than the achievements of students taught with traditional classroom methods. Also, comparisons showed that students learned more than 30 percent faster using CBI than with traditional methods.

Many firms have adopted CBI for training. These firms range from airlines to insurance companies, banks, and federal agencies. The increasing use of CBI by industrial organizations indicates confidence in its usefulness for training. These firms invest capital resources based on analysis of how CBI meets their training requirements. Educational systems are also investing public funds to improve the effectiveness and efficiency of teaching.

Results and Discussion

Several problems must be solved before CBI can be used for technical training in the Navy. First, the characteristics of the CBI programs must be matched to the training requirements, which require an effective planning system. Second, an organization must collect and collate effective existing CBI programs and provide standardization and distribution. As new programs are developed, a system is needed that aids and facilitates the instructional program development process. This system should be computer-based to increase its use and to control the process.

Current textbook-like CBI offers limited gains that result mainly from testing and better management of students' time. However, an insufficient base of scientific knowledge hampers the development and usefulness of advanced CBI systems. A systematic research program is needed to improve this knowledge base and to improve CBI technology.

Conclusions

CBI in its current form can be useful for certain Navy technical training, for example, at remote sites where instructors are unavailable. It can be used to improve training or ensure training is successful and of high quality. The technology requires systematic development, and its use requires careful analysis of the requirements for training supported by CBI.

Recommendations

1. Develop usable procedures to determine when and how to employ CBI effectively for teaching courses and to manage its widespread distribution.

2. Support the development of automated systems to improve instructional program development and systems for collecting and distributing effective programs.

3. Support programmatic research efforts to uncover and apply new knowledge that will make CBI increasingly effective for teaching complicated tasks.

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INTRODUCTION

Purpose and Background

This report briefly summarizes current computer-based instruction (CBI) programs, their effectiveness, and uses.

The potential ability of CBI to manage teaching has been apparent for many years. The difficulty in programming a system to provide the experiences necessary for effective learning, either as a supplement to or as a substitute for a master teacher, has not been apparent. The increasing availability of relatively inexpensive microcomputer power makes this potential attractive because it seems affordable. People fail to consider that computers alone do not contain all the ingredients needed for successful instruction. Those ingredients are provided currently by crude instructional technology that often provides insufficient detail of what needs to be taught, from which prescriptions are made, and how to structure and sequence the interactions with students to promote learning. Then, for CBI, the specifications, prescriptions, and materials must be programmed so a computer can control the process. Computer capabilities have improved to the point that one might imagine could be used to provide a sophisticated learning environment rivaling that of real interactions with tutors and tasks. Unfortunately, before the requirements for such programs can be specified, considerable research is required that explores the relation between students' mental operations, achievement, and instructional methods in learning complicated tasks.

Computers do not provide guidance for large-scale implementation of CBI into instructional programs. Their use poses substantial planning problems, including the need for space, power, instructor training and assignment, student familiarization, etc. Considerable time and energy are needed to plan programs properly. Various reasons for using computers in training situations, other than those in direct instructional interactions, are shown in the following list.

1. Administrative purposes. Accounting, payrolls, employee records, student recordkeeping, attendance, grades, timetables, and planning systems.

2. Curriculum planning. Resource information keeping and planning, production of instructional materials, and test construction.

3. Professional (staff) development and training.

4. Library and data base search for information.

5. Evaluation of programs.

The instructional uses of computers can vary as well. Most CBI has been in the form of an automated workbook, presenting text to be read and questions to test comprehension of the text. When appropriate, pictures and graphs are included. Recently, videotapes and videodiscs have been added to provide dynamic demonstrations and have improved interactivity. Computer graphics provide other ways to represent visual information, but require considerable expertise in computer programming and how best to represent such information to students. Voice synthesizers make audio presentations possible.

Use of computers in training requires talents to analyze and define requirements, determine how instruction should occur, match requirements with capabilities of

computer systems, and program them. Therefore, use of computers in military training must be guided by cautious design plus planning to introduce CBI gradually into instructional programs. Such talents are not readily available. Support must be provided for programmatic research and development efforts to evolve the instructional and software technologies to guide the use of CBI and to enhance the effectiveness of the available talent.

RECENT RESEARCH ON COMPUTER-BASED INSTRUCTION (CBI)

Effectiveness

In general, well designed and appropriately managed CBI does instruct as effectively as well designed traditional methods. CBI is more efficient than alternative ways of delivering the same content. In a few exemplary cases, CBI provides instruction impossible with other means. Whether CBI is worth the cost is an analytical problem that needs more attention (Orlansky & String, 1980).

During the last 15 years, many evaluations have been made of the effectiveness and efficiency of CBI relative to standard, fixed-time lecture courses. Most of these evaluations have compared computerized versions of programmed instruction with content delivered by lecture and text. The usual variables measured in the comparisons were student achievement on accepted achievement tests, how long students took to complete the materials, and whether students or instructors liked it. Some gain in effectiveness was found, for example, achievement test scores for CBI students were the same or a little better, but the overwhelming finding was that students completed the materials faster. Students tended to like CBI because it involved them in the learning process. Instructors, on the other hand, were ambivalent and often negative because they perceive CBI as usurping their role or complicating their lives. The following items summarize some evidence specifically concerned with the effectiveness of CBI, for example, whether it teaches as well as usual methods.

- In comparisons done in 48 military training courses, achievement was about the same in 32 cases, slightly superior in 15 cases, and slightly poorer in 1 case. In 44 cases, completion time was 30 percent faster for the computer-based courses than for the standard courses (Orlansky & String, 1980).

- Careful implementation of CBI in military courses has had positive results on factors related to effective teaching. In contrast to a traditional course, CBI provided better management of the students and increased their time studying the material, their contact with equipment they must learn to use, and their interactions with instructors on the course topics (Van Kekerix, Wulfeck, & Montague, 1982). Using CBI, instructors could use their time normally spent on nonproductive activities, like scoring tests, for more productive teaching tasks. If this extra time was used by teachers to tutor students, students would benefit substantially. Another recent study showed that students learned quickly to recognize radar jamming by using CBI (McDonald & Crawford, 1983). In this evaluation, CBI provided the opportunity to practice rarely encountered events (in peacetime) and an opportunity to use teaching techniques not available with actual equipment. However, management must carefully consider the use of CBI systems to enhance teaching; the Navy has not been entirely successful in enhancing their instructional program development (Montague & Wulfeck, 1982).

• Greater effectiveness of CBI was found in an analysis of 59 independent evaluations of CBI in college courses (Kulik, Kulik, & Cohen, 1980) and in an analysis of 51 independent evaluations of teaching in grades 6 to 12 (Kulik, Bangert, & Williams, 1983). For the college courses, CBI significantly improved students' achievement test performance in 37 comparisons. In grades 6 to 12, the CBI class was superior in 39 of 48 studies measured by final examination scores. For a typical CBI class, scores were raised about .25 standard deviations in the college courses and .32 standard deviations in grades 6 to 12. This means that in the two analyses, the average student in CBI classes outperformed 60 and 63 percent of the students in conventional classes. There was also a positive gain in the attitudes of students toward instruction and toward the subject matter. Only eight evaluations in the college courses and two in grades 6 to 12 were concerned with time spent in instruction (academic education organized around quarters, semesters, or school years seems not to be concerned about efficiency). All 10 studies reported a time savings of 33 percent or greater, which is a substantial improvement and agrees with the military studies cited earlier. Some CBI classes might have shown both performance gains and time savings, but the report is unclear on this point.

Better programming methods developed in artificial intelligence work, theoretical efforts in cognitive science, and hardware developments have stimulated the recent development of generic and intelligent CBI systems. These programs have the potential to approximate the effectiveness of tutorial instruction. Such systems can compare student performance with computer models of students and experts, can infer why a student errs and what is needed to promote learning, and can generate the next interaction. The presentations to the student are not rigidly preprogrammed. These approaches typically will not encompass an entire course, but will focus on critical task training. Thus, they can be included in any system of course management. A large research and development effort is needed to develop this technology.

• A potentially effective use of CBI is as a substitute for costlier (and often unavailable) real equipment or special simulators. Airline and military pilots are using CBI in addition to flight simulators, and substantial savings are claimed for this use of CBI. One of the best current examples of a simulated training system is STEAMER, which trains operators of 1200-pounds-per-square-inch steam power plants for ships (Hollan, Stevens, & Williams, 1980; Hollan, Hutchins, & Weitzman, 1984). Although its instructional effectiveness has not been evaluated, STEAMER has the potential to provide training not possible with current resources that will substantially improve performance. Another example is the present use of a microcomputer to successfully train radar operators to recognize types of jamming (McDonald & Crawford, 1983).

• Another effective use of CBI is the maneuvering board trainer (Hutchins & McCandless, 1982). This system trains Navy officers and enlisted personnel on a task that has historically been difficult to learn. Using simulation techniques derived from cognitive psychology and artificial intelligence, the system provides extensive practice and explanation of difficult navigation problems. Initial tests show that failing students can be brought up to passing grades in less than a third of the time normally taken in the traditional course.

Users

The increasing use of CBI by schools and industry for training and education is a strong indication of its success and usefulness. Selected examples of these uses of CBI are discussed in three groups: (1) profit-making organizations that risk capital to gain efficiencies and provide distribution of training, (2) educational organizations that invest

public funds to improve effectiveness, and (3) sellers and distributors of training programs. For a more complete list of users and distributors, see Kearsley (1983).

Profit-Making

- IBM uses CBI to train about 10,000 field engineers around the country on more than 400 remote terminals. These are located in IBM offices and provide instruction on the function and maintenance of equipment. Materials are in text form (manuals), while testing is on-line to assess mastery of materials. IBM indicates significant savings in travel and per diem costs.

- Insurance companies and banks use CBI to train claim processing agents and tellers. One goal is that training be the same at all the locations. In 1978, Western Bank Corporation installed a financial terminal system and developed a CBI course to put on the new terminals (Rahmelow, 1979). This course trained 6800 tellers and 1500 bank officers at various locations to use the new system.

- American Airlines estimates that CBI and simulation reduced their training time by 50 percent and saved $30 million in fuel (Kearsley, 1983). The Navy has justified its use of computer-based training devices for aircrews on the same basis.

- United Airlines plans to do all its flight training for the Boeing 767 on a CBI system with simulation, thereby reducing the use and cost of special trainers and flying time. Airlines also use terminal systems to train (and upgrade) people to book reservations, calculate fares, and learn other skills.

- Holiday Inns train management personnel in operations and upgrade their training as required on a network of terminals. The system is designed to teach management planning skills.

- The Bell System uses CBI widely for training personnel to install and maintain new equipment. They point to savings in time and travel.

- The oil and gas industry, similarly, provides training at remote locations (training on demand) for their personnel (Rebstock, 1980). This, too, saves travel costs.

- Honeywell uses CBI to train people to use terminals, time-sharing systems, operating systems, programming, report generation, etc. The Digital Equipment Corporation uses CBI to train personnel after purchasing new systems.

- Corporations have been using CBI programs to upgrade the training of engineering technicians because of rapid technology changes (Modesitt, 1981).

- Many departments of the Federal government use CBI for initial training and upgrading of their personnel (e.g., Federal Aviation Administration, Internal Revenue Service, Department of Education, Customs Service, Social Security Administration, and Federal Housing Administration). These agencies adopted CBI because of studies showing that CBI is cost-effective for their application compared to conventional training (Orlansky, personal communication).[1]

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[1] Jesse Orlansky, Institute for Defense Analyses, Arlington, Virginia, phone conversation, 1984.

Educational

• School systems are purchasing networked CBI for mathematics and basic literacy training. Over 150,000 students receive daily training in 24 states, and this has led to significant gains on achievement tests (Suppes, 1979).

• The Philadelphia School District is one of several districts that have been using CBI in education for years. In 1969, Philadelphia secondary schools taught biology and reading courses with CBI, and, during the 1970s, these reading programs were used in both elementary and secondary levels. Hundreds of students use the CBI programs to meet reading comprehension requirements. Recently these programs have been made available on common microcomputers (Kearsley, Hunter, & Seidel, 1983).

• The National Development Programme in Computer-Assisted Learning Project in England developed, with government support, 35 courses at 47 different educational institutions. A specific goal was to produce generalizable, usable programs that would be used after the project support stopped. Currently, most of those courses developed are being used with the costs shared among institutions. The materials are now part of the regular instruction, and the costs are incorporated into regular budgeting (Fielden & Pearson, 1978; Hooper, 1977; Kearsley et al., 1983).

Sellers and Distributors

Another indication of public acceptance is that major firms have been successfully marketing CBI systems and programs for over 10 years and have a multitude of users.

• PLATO began in the early 1960s at the University of Illinois and developed into a large-scale CBI system by the early 1970s. It was adapted for commercial use by the Control Data Corporation, which now sells computers and various training programs to businesses, schools, and individuals through local learning centers. The system has been transferred to microcomputers for wider distribution.

• The TICCIT system was developed as another large-scale time-sharing system using color TV both for text and dynamic imagery. It uses a different instructional approach than other systems to make preparation of materials easier. It is currently being marketed for microcomputers and minicomputers by Hazeltine, Inc. The Navy uses a TICCIT system for part of an aircrew training course.

• Computer Curriculum Corporation sells programs in mathematics and literacy instruction to school districts around the country (Suppes, 1979).

• The increasing availability of inexpensive microcomputers has created a market for instructional software. Over 50 percent of U.S. schools have such systems and do training on them. The problem in such use of computers is keeping track of the software and courseware available for the various machines. Various groups and organizations provide indexing and cataloging of instructional programs. For example, ENTELEK CAI/CMI Catalog and the Index to Computer-Based Learning were early attempts to provide this information (Lekan, 1968; Wang, 1976). Large-scale efforts to distribute programs are CONDUIT, EDUCOM, and MECC. CONDUIT began in the early 1970s at the University of Iowa. It reviews and distributes courseware packages, including student and instructor guides for college courses. EDUCOM was established in the 1960s to promote sharing of computer resources among members (currently about 350 colleges and universities). This is now done electronically over a computer network. The Minnesota Educational

Computing Consortium provides support services and computer program distribution to public school systems. More than 3000 of their microcomputer systems are used in 437 school districts, reaching about 95 percent of primary and secondary students.

RESULTS AND DISCUSSION

This brief review indicates there is sufficient confidence in the efficiency and effectiveness of CBI for profit-making and publicly funded organizations to invest in widespread implementation. Research shows that in contrast with standard, lecture-type instruction, CBI results in equal or somewhat better achievement. Also, students who use CBI may take 30 percent less time to complete a course than students with conventional instruction. Thus, students can perform useful work faster, thereby returning value for the cost of their training. Most of the evidence cited compared large segments or courses of instruction taught conventionally or by CBI. The most valuable uses of CBI, however, may be as devices for critical part-task simulations rather than complete instructional delivery systems. Such systems provide a tutorial learning environment for students and should yield substantial gains in effectiveness in contrast to conventional CBI or classroom instruction. The difficulty in analyzing the learning process and task necessary for programming them makes them rare and expensive. Therefore, careful planning is necessary to develop appropriate CBI, incorporate it into training programs, develop procedures for training managers and instructors, and maintain the systems.

Implicit or explicit in the discussion so far is that there are many reasons for using CBI, most of which are summarized below.

1. Provide students direct contact with tasks to be learned via simulations.
2. Reduce the variability of instruction.
3. Improve security and quality of achievement testing.
4. Reduce requirements for presence of instructors.
5. Make training available at anytime to match student availability.
6. Provide training at remote sites where instructors are unavailable.
7. Reduce training time.
8. Convenience.
9. Reduce travel requirements and per diem expenses for training.
10. Reduce development time for teaching materials and revisions.

Except for the first two, the reasons are concerned with the management of training in a general sense and not with the effectiveness of the learning and instruction process.

The users of CBI already mentioned adopted it after careful study of their requirements and matching them with the capabilities of current systems. Similarly, if existing CBI programs for microcomputers are to be incorporated into Navy instructional programs, the decision to use them should be guided by the knowledge and analysis of how and why they were developed, whether their objectives meet current needs, and evidence of their effectiveness and relative efficiency. Because programs or courseware purchased off the shelf often lack information about their purpose and effectiveness, their introduction may actually interfere with or reduce the quality of instructional programs. A major problem with using traditional CBI is that prospective users are unaware of the limitations of existing techniques and programs.

Even if requirements for instruction are carefully identified and instruction has been well designed, CBI may or may not be the best or only method to deliver it. There may be

good reasons to use a computer to replace a proctor, to deliver pencil and paper tests, to present written text, to guide students through a workbook, to provide extra practice. etc. Decisions to use a computer for any instructional purpose should be based on a careful requirements analysis coupled with good prescriptive guidelines about what interventions will achieve improvement in instruction or in its management. At present, there is little substantive evidence to guide the selection and implementation of traditional CBI systems, let alone more sophisticated, intelligent ones. Alternative means of presenting instruction are possible and can be as effective as CBI, and any choice should be based on costs of developing, implementing, and running the different forms, balanced against their expected outcomes.

To construct instructional programs, the primary problem is the control of the quality of the instructional development process. The use of CBI actually makes the development more difficult. Attention must be given during the analysis and development phases to instructional logic (which an instructor normally does), planning the student-computer interaction and interface, the types of student response data required, the schoolhouse use, and maintainability of the hardware and software. In addition, teachers should be able to modify programs and should learn to use systems whether they develop instruction or use canned programs. This description shows the substantial problems posed in designing a course using a computer for training and in programming the interactions. In order to assist this process, two developments are necessary: automated aids for designing and developing training materials and a coherent software distribution and maintenance system.

Problems encountered in the Navy's instructional program development process (Montague & Wulfeck, 1982, 1984) were largely due to the variable quality of personnel developing the course and the lack of usable operating procedures. Because better written guides cannot solve the problem completely (Montague & Wulfeck, 1982), job aids are needed. Job aids on paper can help, but too much depends on how well the developers learn and use the methods and theory. If the reported gains in productivity by using automated job aids are any guide, such aids for authoring instruction should make substantial differences in the quality of instruction whether it is given on-line or off-line and in the efficiency of instructional program development.

Computerized instructional program development aiding systems can assist with the formidable record keeping problems involved in instructional development. More impressively, they can facilitate the development process itself by guiding test and instructional development and similar tasks. Moreover, computer-based systems can ensure that guidance is followed by monitoring and evaluating developers' performance, especially by forcing attention to the delivery options available and the trade-offs among them and by assisting developers as they proceed. Computer systems can also provide training for instructional developers who can fit it into their work schedules. Finally, these systems are essential for aiding implementation and utilization of CBI. Most CBI users (schools, instructors) want the capability to customize instructional software. Aids for writing, structuring, and editing texts and manuals and graphics editors can be incorporated into the authoring system. This provides an obvious mechanism whereby developing science can improve day-to-day practice. New tools can be included as they are developed.

The transfer of CBI program software is also a problem. There are attempts in civilian education to catalog, annotate, and distribute programs, but none in the military. Even with such cataloging, problems remain. Many Navy activities buy computers that are often not compatible with each other. The software they develop is functionally very similar (e.g., programs to present sections of text and objective test questions). Such

programs require functionally the same code. Computer software companies have recognized the same sort of repetitiveness in computer programs and are developing ways to use code already developed in new programs. This speeds the development process and reduces errors by a large factor. Another problem is that their programs often are not supported by appropriate authoring support and instructional management aids.

To address these problems, families of CBI software should be developed to support CBI for a variety of applications. This can be done by developing libraries of CBI programs sufficiently flexible to support development, delivery, and management to meet many instructional requirements. The library should also be concerned with demonstration of and specifications for generic hardware systems capable of executing library software, and with planning for and assisting institutionalization of CBI programs. By providing transportable, carefully tested CBI software and development tools, compatibility and supportability problems are solved, user requirements are more efficiently addressed, implementation and life-cycle costs are reduced, standard data on student performance and CBI cost-effectiveness can be obtained for budget justification, and acquisition costs of training can be reduced. Most importantly, institutional software libraries can achieve a "critical mass" so that evolutionary improvements through application of new technologies like authoring aids can be achieved.

The Department of Defense is developing a library called TRIADS (Dallman, Pohlman, Psotka, Wisher, McLachlan, Wulfeck, Ahlers, & Cronholm, 1983) to synthesize efforts in all the services related to CBI technology. Initial programs in the TRIADS library are those that have already received rigorous test and evaluation within the developing service. Later, programs will be accepted in the library only after analyses have been conducted and only if they interface with existing authoring and management support aids or include new ones. The purpose of this effort is to develop software and instructional quality standards for programs to be included in the system library, to adapt and enhance existing programs for this system library, to demonstrate the programs, and to develop user training.

Efforts like TRIADS provide straightforward vehicles to put the scientific base to practical use and are essential if CBI is to be widely implemented. However, current lack of funds limits development.

In addition to the development of authoring and distributing systems, programmatic efforts are needed in the psychological and cognitive sciences to develop the knowledge base necessary to prescribe instructional strategies. For example, little is known about the progress of and conditions that promote student learning. Support should be given for research to investigate the design parameters and the effectiveness of various features that might be included in CBI systems.

A number of questions need to be studied. For example, most current CBI systems, like education, use text to communicate materials. Graphics are sometimes used, but no knowledge base exists for prescribing when and how to present these materials. Nor are the effects on student understanding known. Because the visual channel is required in many jobs, CBI is necessary to teach practical tasks. However, current knowledge is insufficient to prescribe exactly when it is needed. A related issue is the use of simulation in training. The psychological features of simulation fidelity cannot be specified to guide the design of training devices.

The effects on student learning and performance of having training systems that understand speech and provide audio messages are unknown. The analysis of the

knowledge and information processing by experts has been suggested to improve the specifications of instructional objectives. However, the methods for doing such analyses vary with researchers. Considerable effort will be needed before sufficient information is available to guide task analysis used to specify design requirements for CBI. The quality of memory for the skills and knowledge learned using CBI has been questioned (Edwards et al., 1975 cited in Kulik et al., 1983). Most research has not assessed retention as part of the evaluation. Although, the few studies that have tested retention show retention was as good for students taught with CBI as for those taught conventionally. Retention is strongly dependent upon initial learning (Hurlock & Montague, 1982). Because CBI produces better learning one would expect better retention. These are only a few of the issues that require a substantial research effort. There is currently little support for the development of this knowledge base necessary for the design of effective training.

CONCLUSIONS

CBI in its current form can be effective for certain Navy training, for example, at remote sites where instructors are unavailable, etc. It can improve the effectiveness, quality, and efficiency of training, and can reduce costs. CBI, therefore, should be used in Navy training, but its introduction should not be precipitous. The CBI technology requires systematic development, and its use requires careful analysis of the requirements for training supported by technology, skillful creation of the training materials by professionals, and thorough evaluation of the technology.

RECOMMENDATIONS

1. Develop usable procedures to determine when and how to employ CBI effectively for teaching courses and to manage its widespread distribution.

2. Support the development of automated systems to improve instructional program development and systems for collecting and distributing effective programs.

3. Support programmatic research efforts to uncover and apply new knowledge that will make CBI increasingly effective for teaching complicated tasks.

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